CLAIMS

1. A method for producing a computer readable definition of a photolithographic mask that defines a pattern in a layer to be formed using the mask, wherein said pattern includes a plurality of features; the method comprising:

identifying cutting areas for phase shift regions based upon characteristics of said pattern;

assigning phase values to phase shift windows in the phase shift regions;

wherein said assigning comprises cutting the phase shift regions in selected ones of the cutting areas to define the phase shift windows; and

storing a result of said laying out and said assigning in a computer readable medium.

2. The method of claim 1, wherein said identifying cutting areas includes:

identifying features in the plurality of features characterized by non-critical process latitude to define a set of features;

identifying fields between features in the plurality of features characterized by critical process latitude to define a set of critical fields; and

defining cutting areas as areas within the phase shift regions which extend between two features in the set of features, or between a feature in a set of features and a field outside the phase shift regions, without intersecting a field in the set of critical fields.

3. The method of claim 1, wherein said assigning comprises applying a cost function to determine the selected ones of the cutting areas.

4. The method of claim 1, wherein said assigning includes ranking said cutting areas based upon characteristics of said pattern, and determining the selected ones of the cutting areas based upon said ranking.

5. The method of claim 1, including laying out said phase shift areas in an opaque background.

6. The method of claim 1, including laying out said phase shift areas in a clear background.

7. The method of claim 1, wherein a characteristic of said pattern used in said identifying cutting areas, is that said pattern includes elbow shaped features.

8. The method of claim 1, wherein a characteristic of said pattern used in said identifying cutting areas, is that said pattern includes T-shaped features.

9. The method of claim 1, wherein a characteristic of said pattern used in said identifying cutting areas, is that said pattern includes polygons larger than a particular size.

10. The method of claim 1, wherein said identifying cutting areas includes determining parameters for said identifying using simulations, based upon simulation criteria which tends to flag features characterized by non-critical process latitude.

11. The method of claim 1, wherein said identifying cutting areas includes determining parameters for said identifying using simulations of over-exposure conditions which tends to flag features characterized by non-critical process latitude.

12. The method of claim 1, wherein said identifying cutting areas includes determining parameters for said identifying using simulations, based upon simulation criteria which tends to flag fields between features in said pattern characterized by critical process latitude.

13. The method of claim 1, wherein said identifying cutting areas includes determining parameters for said identifying using simulations of under-exposure conditions which tends to flag fields between features in said pattern characterized by critical process latitude.

14. The method of claim 1, wherein said assigning phase shift values includes defining a first set of phase shift window inducing θ degrees phase shifting and a second set of phase shift windows inducing ϕ degrees phase shifting.

15. The method of claim 14, wherein ϕ is equal to approximately $\theta + 180$ degrees.

16. A data processing system, comprising:

a processor;

a machine readable data storage medium coupled to the processor, having stored thereon instructions executable by the processor defining steps for laying out a photolithographic mask that defines a pattern in a layer to be formed using the mask, wherein said pattern includes a plurality of features, the steps comprising:

identifying cutting areas for phase shift regions based upon characteristics of said pattern;

assigning phase values to phase shift windows in the phase shift regions;

wherein said assigning comprises cutting the phase shift regions in selected ones of the cutting areas to define the phase shift windows; and

storing a result of said laying out and said assigning in a computer readable medium.

17. The data processing system of claim 16, wherein said identifying cutting areas includes:

identifying features in the plurality of features characterized by non-critical process latitude to define a set of features;

identifying fields between features in the plurality of features characterized by critical process latitude to define a set of critical fields; and

defining cutting areas as areas within the phase shift regions which extend between two features in the set of features, or between a feature in a set of features and a field outside the phase shift regions, without intersecting a field in the set of critical fields.

18. The data processing system of claim 16, wherein said assigning comprises applying a cost function to determine the selected ones of the cutting areas.

19. The data processing system of claim 16, wherein said assigning includes ranking said cutting areas based upon characteristics of said pattern, and determining the selected ones of the cutting areas based upon said ranking.

20. The data processing system of claim 16, including laying out said phase shift areas in an opaque background.

21. The data processing system of claim 16, including laying out said phase shift areas in a clear background.

22. The data processing system of claim 16, wherein a characteristic of said pattern used in said identifying cutting areas, is that said pattern includes elbow shaped features.

23. The data processing system of claim 16, wherein a characteristic of said pattern used in said identifying cutting areas, is that said pattern includes T-shaped features.

24. The data processing system of claim 16, wherein a characteristic of said pattern used in said identifying cutting areas, is that said pattern includes polygons larger than a particular size.

25. The data processing system of claim 16, wherein said assigning phase shift values includes defining a first set of phase shift window inducing θ degrees phase shifting and a second set of phase shift windows inducing ϕ degrees phase shifting.

26. The data processing system of claim 25, wherein ϕ is equal to approximately θ + 180 degrees.

27. An article of manufacture, comprising:

a machine readable data storage medium, having stored thereon instructions executable by a data processing system defining steps for laying out a photolithographic mask that defines a pattern in a layer to be formed using the mask, wherein said pattern includes a plurality of features, the steps comprising:

identifying cutting areas for phase shift regions based upon characteristics of said pattern;

assigning phase values to phase shift windows in the phase shift regions;

wherein said assigning comprises cutting the phase shift regions in selected ones of the cutting areas to define the phase shift windows; and

storing a result of said laying out and said assigning in a computer readable medium.

28. The article of claim 27, wherein said identifying cutting areas includes:

identifying features in the plurality of features characterized by non-critical process latitude to define a set of features;

identifying fields between features in the plurality of features characterized by critical process latitude to define a set of critical fields; and

defining cutting areas as areas within the phase shift regions which extend between two features in the set of features, or between a feature in a set of features and a field outside the phase shift regions, without intersecting a field in the set of critical fields.

29. The article of claim 27, wherein said assigning comprises applying a cost function to determine the selected ones of the cutting areas.

30. The article of claim 27, wherein said assigning includes ranking said cutting areas based upon characteristics of said pattern, and determining the selected ones of the cutting areas based upon said ranking.

31. The article of claim 27, including laying out said phase shift areas in an opaque background.

32. The article of claim 27, including laying out said phase shift areas in a clear background.

33. The article of claim 27, wherein a characteristic of said pattern used in said identifying cutting areas, is that said pattern includes elbow shaped features.

34. The article of claim 27, wherein a characteristic of said pattern used in said identifying cutting areas, is that said pattern includes T-shaped features.

35. The article of claim 27, wherein a characteristic of said pattern used in said identifying cutting areas, is that said pattern includes polygons larger than a particular size.

36. The article of claim 27, wherein said assigning phase shift values includes defining a first set of phase shift window inducing θ degrees phase shifting and a second set of phase shift windows inducing ϕ degrees phase shifting.

37. The article of claim 36, wherein ϕ is equal to approximately θ + 180 degrees.

38. A photolithographic mask for defining a pattern in a layer to be formed using the mask, wherein said pattern includes a plurality of features, and said layer includes fields outside said pattern, comprising:

a substrate;

a mask layer of material on said substrate;

the mask layer including phase shift regions and fields, and a plurality of phase shift windows in the phase shift regions, the plurality of phase shift windows characterized by phase shift values that create phase transitions between the phase shift windows to form said pattern, wherein the wherein the boundaries of the phase shift windows lie within cutting areas that are defined based upon characteristics of said pattern.

39. The mask of claim 36, wherein a set of features in the plurality of features are characterized by non-critical process latitude, and a set of critical fields between features in the plurality of features are characterized by critical process latitude; and

said cutting areas include areas within the phase shift regions which extend between two features in the set of features, or between a feature in the set of features and a field outside the phase shift regions, without intersecting a field in the set of critical fields.

40. The mask of claim 36, wherein the mask layer comprises an opaque material.

41. The mask of claim 36, wherein the mask layer comprises a clear material.

42. The mask of claim 36, wherein a characteristic of said pattern used in defining cutting areas, is that said pattern includes elbow shaped features.

43. The mask of claim 36, wherein a characteristic of said pattern used in defining cutting areas, is that said pattern includes T-shaped features.

44. The mask of claim 36, wherein a characteristic of said pattern used in defining cutting areas, is that said pattern includes polygons larger than a particular size.

45. The mask of claim 36, wherein said phase shift values include θ degrees phase shifting and ϕ degrees phase shifting, wherein ϕ is equal to approximately θ + 180 degrees.

46. A method for manufacturing a photolithographic mask that defines a pattern in a layer to be formed using the mask, wherein said pattern includes a plurality of features; the method comprising:

identifying cutting areas for phase shift regions based upon characteristics of said pattern;

assigning phase values to phase shift windows in the phase shift regions;

wherein said assigning comprises cutting the phase shift regions in selected ones of the cutting areas to define the phase shift windows; and

applying a result of said laying out and said assigning to formation of a mask layer on a substrate.

47. The method of claim 46, wherein said identifying cutting areas includes:

identifying features in the plurality of features characterized by non-critical process latitude to define a set of features;

identifying fields between features in the plurality of features characterized by critical process latitude to define a set of critical fields; and

defining cutting areas as areas within the phase shift regions which extend between two features in the set of features, or between a feature in a set of features and a field outside the phase shift regions, without intersecting a field in the set of critical fields.

48. The method of claim 46, wherein said assigning comprises applying a cost function to determine the selected ones of the cutting areas.

49. The method of claim 46, wherein said assigning includes ranking said cutting areas based upon characteristics of said pattern, and determining the selected ones of the cutting areas based upon said ranking.

50. The method of claim 46, including laying out said phase shift areas in an opaque background.

51. The method of claim 46, including laying out said phase shift areas in a clear background.

52. The method of claim 46, wherein a characteristic of said pattern used in said identifying cutting areas, is that said pattern includes elbow shaped features.

53. The method of claim 46, wherein a characteristic of said pattern used in said identifying cutting areas, is that said pattern includes T-shaped features.

54. The method of claim 46, wherein a characteristic of said pattern used in said identifying cutting areas, is that said pattern includes polygons larger than a particular size.

55. The method of claim 46, wherein said identifying cutting areas includes determining parameters for said identifying using simulations, based upon simulation criteria which tends to flag features characterized by non-critical process latitude.

56. The method of claim 46, wherein said identifying cutting areas includes determining parameters for said identifying using simulations of over-exposure conditions which tends to flag features characterized by non-critical process latitude.

57. The method of claim 46, wherein said identifying cutting areas includes determining parameters for said identifying using simulations, based upon simulation criteria which tends to flag fields between features in said pattern characterized by critical process latitude.

58. The method of claim 46, wherein said identifying cutting areas includes determining parameters for said identifying using simulations of under-exposure conditions which tends to flag fields between features in said pattern characterized by critical process latitude.

59. The method of claim 46, wherein said assigning phase shift values includes defining a first set of phase shift window inducing θ degrees phase shifting and a second set of phase shift windows inducing ϕ degrees phase shifting.

60. The method of claim 59, wherein ϕ is equal to approximately θ + 180 degrees., comprising:

61. A method for manufacturing a layer of material in an integrated circuit, the layer of material having a pattern, wherein said pattern includes a plurality of features, comprising:

using a photolithographic mask to define the layer of material, wherein the mask comprises a substrate; and a mask layer of material on said substrate, wherein the mask layer includes phase shift regions and fields, and a plurality of phase shift windows in the phase shift regions, the plurality of phase shift windows characterized by phase shift values that create phase transitions between the phase shift windows to form said pattern, wherein the boundaries of the phase shift windows lie within cutting areas that are defined based upon characteristics of said pattern.

62. The method of claim 61, wherein a set of features in the plurality of features are characterized by non-critical process latitude, and a set of critical fields between features in the plurality of features are characterized by critical process latitude; and

said cutting areas include areas within the phase shift regions which extend between two features in the set of features, or between a feature in the set of features and a field outside the phase shift regions, without intersecting a field in the set of critical fields.

63. The method of claim 62, wherein the mask layer comprises an opaque material.

64. The method of claim 63, wherein the mask layer comprises a clear material.

65. The method of claim 64, wherein a characteristic of said pattern used in defining cutting areas, is that said pattern includes elbow shaped features.

66. The method of claim 61, wherein a characteristic of said pattern used in defining cutting areas, is that said pattern includes T-shaped features.

67. The method of claim 61, wherein a characteristic of said pattern used in defining cutting areas, is that said pattern includes polygons larger than a particular size.

68. The method of claim 61, wherein said phase shift values include θ degrees phase shifting and ϕ degrees phase shifting, wherein ϕ is equal to approximately $\theta + 180$ degrees.

69. The method of claim 61, including after using said photolithographic mark, using a second photolithographic mask.

70. An integrated circuit manufactured according to a process comprising:

using a photolithographic mask to define the layer of material on the integrated circuit, wherein the mask comprises a substrate; and a mask layer of material on said substrate, wherein the mask layer includes phase shift regions and fields, and a plurality of phase shift windows in the phase shift regions, the plurality of phase shift windows characterized by phase shift values that create phase transitions between the phase shift windows to form said pattern, wherein the boundaries of the phase shift windows lie within cutting areas that are defined prior to assigning of phase shift values, according to characteristics of said pattern.

71. The integrated circuit of claim 70, wherein a set of features in the plurality of features are characterized by non-critical process latitude, and a set of critical fields between features in the plurality of features are characterized by critical process latitude; and

said cutting areas include areas within the phase shift regions which extend between two features in the set of features, or between a feature in the set of features and a field outside the phase shift regions, without intersecting a field in the set of critical fields.

72. The integrated circuit of claim 70, wherein the mask layer comprises an opaque material.

73. The integrated circuit of claim 70, wherein the mask layer comprises a clear material.

74. The integrated circuit of claim 70, wherein a characteristic of said pattern used in defining cutting areas, is that said pattern includes elbow shaped features.

75. The integrated circuit of claim 70, wherein a characteristic of said pattern used in defining cutting areas, is that said pattern includes T-shaped features.

76. The integrated circuit of claim 70, wherein a characteristic of said pattern used in defining cutting areas, is that said pattern includes polygons larger than a particular size.

77. The integrated circuit of claim 70, wherein said phase shift values include θ degrees phase shifting and ϕ degrees phase shifting, wherein ϕ is equal to approximately θ + 180 degrees.

78. The integrated circuit of claim 70, including after using said photolithographic mark, using a second photolithographic mask.

79. An integrated circuit having a patterned layer of material characterized by a dense set of small dimension features, the small dimension features defined using alternate phase shift masking, and placed in close proximity to other small dimension features.

80. A method of generating a phase shifted representation of a layer of an integrated circuit, the method comprising:

selecting a plurality of structures in a first layer representation of the integrated circuit for definition using a phase shift representation;

defining a plurality of phase shift regions in the phase shift representation for use in defining the plurality of structures;

identifying a plurality of cutting areas in the plurality of phase shift regions, the plurality of cutting areas indicating locations where a phase shift region in the plurality of phase shift regions can be divided into phase shift windows;

ranking the plurality of cutting areas;

identifying, and assigning phase values to, phase shift windows in the phase shift representation by selectively using the plurality of cutting areas and the ranking to resolve phase conflicts; and

generating a second representation of the first layer representation for use in conjunction with the phase shifting region.

81. The method of claim 80, wherein the second representation comprises a binary trim mask representation for protecting the plurality of structures defined by the phase shift representation and defining other structures in the first layer representation.

82. The method of claim 80, wherein the second representation comprises an attenuated binary trim mask representation.

83. The method of claim 80, wherein the ranking comprises treating each of the plurality of cutting areas as equally ranked.

84. The method of claim 80, wherein the plurality of cutting areas includes a first cutting area and a second cutting area, and wherein the first cutting area ranked as preferred over the second cutting area for selection during the assigning.

85. The method of claim 84, wherein the first cutting area comprises a cut to field and the second cutting area comprises a cut around a contact hole.

86. The method of claim 80, wherein the first layer representation comprises a second plurality of structures and wherein the selecting comprises selecting as the plurality of structures substantially all of the structures in the second plurality of structures.

87. The method of claim 80, wherein the assigning further comprises:

using each of the plurality of cutting areas to divide the plurality of phase shift regions into a plurality of phase shift windows;

assigning phase to each of the plurality of phase shift windows; and

selectively merging phase shift windows in the plurality of windows to reduce number of phase shift windows using the ranking.

88. The method of claim 80, wherein the assigning further comprises:

representing the plurality of phase shift regions and plurality of cutting areas using a graph data structure, the graph data structure representing the ranking and phase conflicts;

determining phase assignments using the graph data structure.

89. The method of claim 88, wherein the determining phase assignments further comprises identifying phase conflicts as cycles of odd length in the graph data structure.

90. An electromagnetic waveform embodied on a carrier wave, the electromagnetic waveform comprising a computer program for assigning phase to a plurality of phase shifting regions in a phase shifting representation of a layer of an integrated circuit, the computer program further comprising:

a first set of instructions for identifying a plurality of cutting areas in the phase shifting representation, the plurality of cutting areas specifying locations where a phase shift region in the plurality of phase shift regions can be divided into multiple phase shift windows;

a second set of instructions for ranking the plurality of cutting areas;

a third set of instructions for identifying, and assigning phase to, each of the plurality of phase shift windows in the phase shift representation by selectively using cutting areas in the plurality of cutting areas and the ranking of the plurality of cutting areas to resolve phase conflicts.

91. The electromagnetic waveform of claim 90, wherein the layer of the integrated circuit includes a plurality of structures and wherein the phase shift representation is used for defining a substantially all of the plurality of structures using the plurality of phase shifting regions.

92. The electromagnetic waveform of claim 90, wherein the computer program further comprises a fourth set of instructions for generating a second representation of the layer of the integrated circuit, the second representation designed for use in conjunction with the phase shifting representation to protect structures defined by the phase shifting representation and define additional structures in the layer.

93. The electromagnetic waveform of claim 90, wherein the third set of instructions further comprises a set of instructions for assigning phase while minimizing number of cuts from the plurality of cutting areas during the selectively using.

94. The electromagnetic waveform of claim 90, wherein the second set of instructions further comprises:

a fourth set of instructions for analyzing a first representation of the layer of the integrated circuit to identify a plurality of features of high process latitude in the layer;

a fifth set of instructions for analyzing the first representation of the layer of the integrated circuit to identifying a plurality of areas of field between features characterized by critical process latitude in the layer; and

a sixth set of instructions for defining the plurality of cutting areas at locations within phase shift regions extending between at least one of:

two features in the plurality of areas of high process latitude and a feature in the plurality of features of high process latitude and field outside the plurality of phase shift regions without intersecting the plurality of areas of field between features characterized by critical process latitude.

95. The electromagnetic waveform of claim 90, wherein the computer program is designed for execution in parallel on one or more processors and the electromagnetic waveform comprises the computer program accessed over a network.